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ON NEWTON'S USE OF THE TERM INDIGO WITH REFERENCE TO A COLOR OF THE SPECTRUM.

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On a Method of Studying the Reflexion of Sound-Waves; by O. N. Rood, Professor of Physics in Columbia College.

It has been the custom for several years to introduce in certain forms of the melodeon a revolving fan for the purpose of obtaining rapid alternations in the intensity of the notes. This arrangement is called a "tremolo," and its action was considered by its inventor and by those interested in it to depend on the currents of air produced by the motion of the fan. An examination of the apparatus soon convinced me that this idea was erroneous, and that the alternations in the loudness of the sound was due to reflexion or non-reflexion from the face of the revolving fan, for I found that the same effects could be produced by the aid of a circular disc consisting of open and closed sectors and revolving in its own plane. A disc of this kind constitutes a useful piece of apparatus for studying the reflexion of sound-waves, and some results obtained with it were communicated by me to the National Academy of Sciences, as long ago as October, 1876.

As no account of these experiments has ever been published, a short description of them may not be without interest to those engaged in experimental researches on sound, as with their aid the following facts may be easily demonstrated:

1*st. At a perpendicular incidence the short sound-waves are more copiously reflected than those that are longer, and the regular reflexion is more copious from large than from small surfaces.*

The diameter of the zinc disc was in the first set of experiments 21 inches =53·3 centimeters; alternate quadrants were removed, and the rate of rotation varied from two to four turns in a second. The tuning-forks were mounted on their resonance boxes and gradually removed away from the revolving disc till the alternations could no longer be distinguished by the ear placed near the fork. The results are given in the table below, in which "distance" indicates that of the open end of the tuning-fork from the disc:

Diameter of disc				21	inches.	
Ut_3	fork;	alternations	heard at	13	"	distance.
Ut_4	"	"	"	20	"	"
Ut_5	"	"	"	96	"	"

When the same experiments were made with a disc having a diameter of only $8\frac{1}{2}$ inches or 21·5 centimeters, it was found necessary to bring the forks much nearer to the disc before the alternations could be perceived.

Diameter of disc		$8\frac{1}{2}$	inches.	
Ut_3 fork; alternations heard at		2	"	distance.
Ut_4 "	"	" 3	"	"
Ut_5 "	"	" 6	"	"

2*d*. *When the sound-waves fall upon small flat surfaces at an acute angle, the reflexion is most copious in the same direction as with light, but the reflected and inflected waves can be traced all around the semicircle.*

Experiments on this point were made in the open air, the larger disc being used with angles of 60° and 70° (from the perpendicular); the Ut_4 and Ut_5 forks were employed.

The regularly reflected waves could be heard at a distance of ten or twenty feet from the disc, the fork being held a foot or two from it; inflected waves were easily distinguishable all around the disc and even a few feet *behind* the fork.

When the forks were placed in the plane of the disc the alternations of loudness were reduced to a minimum, but in the open air and in a room never wholly disappeared. This I suppose to be owing to the fact that the source of sound is not a point but a surface. Even under these circumstances, feeble alternations were heard all around the disc, the inflected waves actually returning to their source. With a plain disc alternations were not perceived.

3*d*. *Qualitative comparisons between the power of different substances to reflect sound can easily be made.*

For example, a disc of card-board in which filter paper is fastened over the open sectors gives alternations, owing to the difference of the reflective powers of the two substances.

4*th*. *If a composite sound-wave falls on the rotating disc the shorter waves will undergo regular reflexion more copiously than the other components.*

This experiment is most easily made with a reed without its pipe. Ut_3, Ut_4, Ut_5 reeds give alternations but mainly in their high overtones; the alternations consequently have a ringing metallic sound.

5*th*. *The reflexion of sound from very small surfaces is easily demonstrated.*

If an Ut_3 or Ut_4 reed without its pipe be employed, alternations are easily obtained by moving a visiting card properly near the reed. By substituting a gas-flame for the card the reflexion from the flame can be demonstrated. The gas-burner should be attached to a long slender rod.

Almost all of these experiments are so easily performed as to be suitable for lecture-room purposes.

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On Newton's use of the term Indigo with reference to a Color of the Spectrum; by Professor O. N. Rood, of Columbia College.

The coloring matter known as indigo has a dingy, dark blue color, which scarcely qualifies it to rank as a representative of one of the pure brilliant colors of the spectrum. Von Bezold has already objected to its use on account of the *darkness* of the tint, but in the present paper I propose to show that in another and more important respect it is equally inapplicable. Newton intended to designate by it the color of that part of the spectrum which is situated between the blue and violet; indigo, however, is really a representative, though a poor one, of an entirely different region of the spectrum, as will be shown by the following considerations.

Experiments were first made with three different samples of indigo in order to see whether important differences in hue existed when the substance was prepared by different persons. One of the best methods of studying the hue of a colored surface is to ascertain the nature and amount of the colored light which is complementary to it. Discs of card board were accordingly painted with indigo as a water-color pigment and these were combined by Maxwell's method with two discs painted with chrome yellow and vermilion, and neutralization effected by rapid rotation.

Indigo as a water-color pigment (prepared by Winsor and Newton).

Ratio of red and yellow necessary to neutralize it.

Chrome-yellow, 67. Vermilion, 33.

Indigo as a water-color pigment (prepared by Barnard).

Chrome-yellow, 65. Vermilion, 35.

Dry commercial indigo was then rubbed on white drawing paper, and gave a result similar to those just detailed; the ratio was:

Chrome-yellow, 62. Vermilion, 38.

In the dry state the color was then a little more greenish, a slightly larger quantity of the vermilion being required; the three experiments, however, substantially agree.

A solution of commercial indigo in water was also compared with the discs, and seemed to agree well with them.

Instead of comparing one of the dingy indigo discs directly with the brilliant-colored spaces of the spectrum, I made an accurate comparison of its color with that of a disc painted with Prussian blue, reserving the latter for direct comparison with the spectrum.

The Winsor and Newton disc which the previous experiment had proved to be the least greenish in hue, was now combined with one of vermilion and emerald green, and the following equation obtained:

I 51·4+V 29+G 19·6 =32·8 white. A disc of Prussian blue similarly treated gave P.b. 39·9+V 35·7+G 24·4 =27·4 white.

These equations prove that the *hue* of the indigo and Prussian blue discs were identical, for the ratio of the red and green required to effect neutralization is the same, being in the case of the indigo, 59·7 vermilion to 40·3 emerald green; in that of the Prussian blue, 59·4 vermilion to 40·6 emerald green.

The position of the Prussian blue disc in the normal spectrum was now determined with the aid of a large spectrometer, the eye-piece being provided with a slit which excluded all except a narrow slice of the spectrum. Such determinations can be made by a practiced eye with considerable certainty, as I propose to show at some future time. It was found that in a normal spectrum including from A to H 1000 parts the position of Prussian blue was at a distance from A equal to 740 of these parts. Now according to my observations on this spectrum, blue-green ends and cyan-blue begins at 698; also cyan-blue ends and blue begins at 749; hence the color of Prussian blue falls in the cyan-blue space near the beginning of the blue, and to this same position we must consequently refer the color of indigo.

It afterwards occurred to me that possibly Newton might have used the indigo in the dry lump, and accordingly I prepared a flat surface of dry commercial indigo and compared it carefully with the blue furnished by genuine and artificial ultramarine, its color being of course enormously darker, or one might say, blacker than that of either of these substances. A mixture by rotation of six parts of artificial ultramarine blue with two parts white and ninety-two parts black gives a color more or less like that of commercial indigo in the dry cake: that is to say, if a freshly *fractured* surface of indigo be compared with the compound disc just mentioned, the color of the indigo will be found somewhat too greenish; but on the other hand, if a *scraped* surface of the dry cake is used it will be too purplish. Newton therefore probably employed his indigo in the dry state.

I give below, according to my determinations, the positions and corresponding wave-lengths of indigo, Prussian blue, cobalt-blue, genuine ultramarine-blue and artificial ultramarine-blue, in a normal spectrum having from A to H 1000 parts.

	Position in normal spectrum.	Wave-length in $\frac{1}{10000000}$ mm.
Indigo, Prussian blue,	740	4899
Cobalt-blue,	770	4790
Ultramarine (genuine),	785	4735
Ultramarine (artificial),	857	4472

It has been shown then,

1st. That the color of indigo is really a greenish blue when it is used as a pigment or in solution.

2d. The color of the dry cake is not only very black, but variable according to the mode in which it is handled.

Taking all this into consideration, it would appear desirable to allow the term indigo to fall into disuse, and to substitute for it ultramarine, the color of the artificial variety being intended.